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Forest Growth of Mississippi's North Unit—A Case Study of the Southern Forest Survey's Growth Estimation Procedures

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SUMMARY

This report presents the procedures by which the Southern Forest Inventory and Analysis unit estimates forest growth from permanent horizontal point samples. Inventory data from the 1977-87 survey of Mississippi's north unit were used to demonstrate how trees on horizontal point samples are classified into one of eight components of growth (survivor growth, ingrowth, mortality growth, cut growth, cull increment, mortality, cut, or landclearing) and, in turn, how these components are combined to derive estimates of forest growth (gross growth, net growth, and net change). Results indicate that the current growth estimation procedures provide reasonable and unbiased estimates of growth, removals, and mortality while providing statistically additive estimates of net change.

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INTRODUCTION

One objective of the Southern Forest Inventory and Analysis (FIA) unit is to periodically assess forest growth (gross growth, net growth, and net change) for each state in the Midsouth region. Before the 1980 survey of Tennessee, growth estimates were calculated for the calendar year prior to the year of the inventory, with the inventory being dated on the January 1 closest to the midpoint of the field work in a state. These growth estimates were composed of six main components: survivor growth, ingrowth, growth on ingrowth, growth on cut, mortality, and cut. Periodic annual estimates of the first five were derived from permanent horizontal point samples (HPS). The last component (cut) was derived mainly from canvasses of forest industry timber consumption. Estimates of other removals (trees that were killed for stand improvement, killed by logging, or removed in landclearings) derived from permanent HPS were also included in the cut component. As a result, the growth estimates were a mixture of sample estimates and deterministic measures. During the 1980 survey of Tennessee, the transition to calculating all growth components from permanent HPS was made. By the 1982 survey of Alabama, the Beers and Miller (1964) approach to estimating growth and growth components from permanent HPS was incorporated into the Southern FIA data reduction procedures.

Alabama's growth estimates using the Beers and Miller approach were criticized because the old inventory plus the net change did not sum to the new inventory. Under this approach to forest growth estimation, unbiased estimates of forest growth can be obtained. Additivity, however, is not assured because of 1) intersurvey population differences caused by additions to or deletions from the forest land base due to reversions or landclearings and 2) differences in successive HPS caused by trees growing onto the points over the survey period. The trees that grow onto the HPS can be divided into two types: those that were of merchantable size at the first survey (nongrowth) and those that were not (ongrowth) (Martin 1982). Under the Beers and Miller approach, only ongrowth trees are accounted for in the growth estimation procedures, hence the problem of additivity due to the exclusion of nongrowth trees. To continue to provide unbiased estimates of growth, as well as enhance additivity, the Southern FIA adopted the growth estimation procedures proposed by Van Deusen, Dell, and Thomas (1986). Their approach employs a new estimator of survivor growth for remeasured HPS that adjusts for the nongrowth trees excluded by the Beers and Miller approach, thus alleviating one of the reasons for nonadditivity. This "additive" approach has been in place in the Southern FIA data reduction procedures since the 1984 survey of Louisiana. To date, it has been used in Texas, Oklahoma, and Mississippi.

CURRENT GROWTH ESTIMATION PROCEDURES

Although minor refinements have been made to accommodate state-to-state changes in field techniques, the growth estimation procedures have remained essentially the same for all states subsequent to Louisiana 1984. Currently, separate estimates of growth are calculated for the growing-stock and sawtimber portions of the inventory. With the use of attribute filters (appendices 1, 2 and 3) trees on Southern FIA plots (permanent HPS) are processed into one of the following growth components or subcomponents thereof:

Survivor Growth

Survivors.—Trees that survived from the first survey to the second survey and were of merchantable size and growing-stock quality in both surveys. Estimates of survivor growth for these trees are based on the difference between the volume and number of trees in the second survey and the volume and number of trees in the first survey—the change in volume to basal area ratio.

Nongrowth.—Trees that grew onto the plot over the survey period and fell outside the plot defined by the limiting distance of the minimum size merchantable tree and were of merchantable size (based on predicted past diameter) and growing-stock quality in both surveys. Their estimates of survivor growth are based on the volume and number of trees in the second survey.

Ingrowth

Ingrowth.—Trees that were tallied and of submer-

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chantable size in the first survey but were of merchantable size and growing-stock quality in the second survey.

Ongrowth.—Trees that grew onto the plot over the survey period and fell within the plot defined by the limiting distance of the minimum size merchantable tree or were of submerchantable size in the first survey (based on predicted past diameter), but were of merchantable size and growing-stock quality in the second survey. The estimates of ingrowth for both subcomponents are based on the volumes and numbers of trees in the second survey.

Mortality Growth

Mortality.—Trees of merchantable size and growing-stock quality in the first survey that died before the second survey. Estimates of mortality growth for them are based on the volume change between the first survey and the time of death and the past number of trees.

Mortality Ingrowth.—Trees that were tallied and of submerchantable size and growing-stock quality in the first survey that grew to merchantable size and died before the second survey. Estimates of mortality growth for these trees are based on the volume at the time of death and the past number of trees.

Cut Growth

This component accounts for the growth of trees that were cut (trees removed for timber products, killed during logging, or killed for stand improvements) during the intersurvey period. The cut growth component handles cut trees in the same manner that the mortality growth component handles dead trees.

Cull Increment

These are trees that changed tree classes between surveys (from growing-stock quality to cull or vice versa), resulting in an imbalance in the growth estimates due to trees being included in one survey but not the other. These trees fall into one of the two following subcomponents:

Sound to Cull.—Trees of merchantable size that were of growing-stock quality in the first survey but cull in the second survey. Balance is attained by subtracting a volume estimate based on the volume and number of trees in the first survey from the growth estimates.

Cull to Sound.—Trees of merchantable size that were cull in the first survey but of growing-stock quality in the second survey. Balance is attained by adding a volume estimate based on the volume and number of trees in the second survey to the growth estimates.

Mortality

This component is composed of the same two subcomponents that make up the mortality growth component. The estimates of mortality volume for both subcomponents are based on the volume at the time of death and the number of trees at the first survey.

Cut

This component is handled in the same manner as the mortality component, except for the use of cut trees in place of mortality trees.

Landclearing

This component includes trees on forested plots that were of merchantable size and growing-stock quality in the first survey that, because of a land-use change, are classified as being on nonforest plots in the second survey. The estimates of the volumes landcleared are based on the volume and number of trees at the first survey.

The component volumes for each tree are expanded to the county level using the remeasured expansion factor. The remeasured expansion factor is the current number of forested acres represented by each remeasured plot in a county. Plots that have reverted to forest and those that have been cleared are not considered to be remeasured plots. As a result, reversions receive the average growth of remeasured plots in a county, and landclearing volume estimates are expanded to the county level by the expected expansion factor for a Southern FIA plot, 5,760 acres. Because reverted and cleared plots occur infrequently in most counties and the true number of acres they represent cannot be ascertained under the current sampling scheme, this method of handling reversion growth and landclearing removals is acceptable. From this point, the county level component volumes for each tree are either summed to yield periodic component estimates or divided by the intersurvey period for each plot and then summed to yield average annual component estimates. The algorithms used to process sample tree component volumes are shown in appendices 2 and 3. From the component estimates, county, unit, or state level estimates of forest growth (gross growth, net growth, and net change) can be derived.

GROWTH ESTIMATES AND COMPONENTS FOR MISSISSIPPI'S NORTH UNIT

The recently completed 1977-87 inventory of the north unit of Mississippi provides an example of how forest growth estimates are derived from growth component estimates (table 1.). The growth components are logically organized into two categories—those that add to the initial inventory and those that subtract from it. The four components that increment the initial inventory are survivor growth, ingrowth, mortality growth, and cut growth. The sum of these four growth components is an estimate of gross growth.

Table 1.—*Periodic growth components and estimates of gross growth, net growth, and inventory change for Mississippi's north unit, 1977-87*[1]

Growth estimate[2]	Growth component	Subcomponent	Softwood	Hardwood	Total
			Million cubic feet		
	Survivor growth	Survivors	272.2	270.2	542.4
(+)		Nongrowth	625.7	723.1	1,348.8
		Total	897.9	993.3	1,891.2
	Ingrowth	Ingrowth	36.1	27.2	63.6
(+)		Ongrowth	103.5	103.3	206.8
		Total	139.9	130.6	270.5
	Mortality growth	Mortality	46.0	25.1	71.1
(+)		Mortality ingrowth	43.8	12.1	55.9
		Total	89.8	37.2	127.0
	Cut growth	Cut	240.1	95.8	335.9
(+)		Cut ingrowth	42.1	20.7	62.8
		Total	282.2	116.5	398.7
Total Gross growth			1,409.7	1,277.7	2,687.4
	Cull increment	Sound to cull	-26.5	-120.3	-146.8
(+ -)		Cull to sound	+14.9	+145.2	+160.1
		Total	-11.6	+24.9	+13.3
Total Adjusted gross growth			1,398.1	1,302.6	2,700.7
	Mortality	Mortality	161.6	170.5	332.1
(-)		Mortality ingrowth	43.8	12.1	55.9
		Total	205.3	182.6	388.0
Total Net growth			1,192.8	1,119.9	2,312.7
	Cut	Cut	957.5	577.2	1,534.7
(-)		Cut ingrowth	42.1	20.7	62.8
		Total	999.6	597.9	1,597.5
(-)	Landclearing	Landclearing	69.2	108.2	177.3
(-)	Total removal		1,068.8	706.1	1,774.9
Total Net change			124.0	413.8	537.8

[1]Columns may not add due to rounding.

[2](+) or (-) indicate whether the subcomponent increments or decrements the initial inventory.

Gross Growth

In the north unit, gross growth, the measure of the initial inventory's gross increase over the survey period, averaged 6.8 percent per year, for a total increase of 66.5 percent for the period. The survivor growth component constitutes 70 percent of the gross growth estimate. The nongrowth subcomponent, in turn, accounts for 70 percent of the survivor growth component. Because of the magnitude of the nongrowth subcomponent, which individually accounts for half of the gross growth estimate, the inclusion of nongrowth trees in the survivor growth component would seemingly overestimate growth. However, this is not the case. Under the current growth estimation procedures, nongrowth serves to offset the effect of survivor trees growing larger over the intersurvey period and having a corresponding smaller expansion to the acre (Van Deusen and others 1986, Martin 1982).

Ingrowth, the next component that serves to increment the initial inventory, contributes 10 percent of the gross growth estimate for the north unit. The ongrowth subcomponent accounts for three-quarters of this component's contribution to gross growth.

The contributions of the two remaining components of gross growth, mortality growth and cut growth, are dependent upon three factors: 1) the amount of mortality or cut during the intersurvey period, 2) the growth rate of the trees before death or removal, and 3) the elapsed time between the initial survey and the time of death or removal. The combined effect of these three factors is the reason for cut growth's 15 percent contribution to the gross growth of the north unit being three times that of mortality growth.

Adjusted Gross Growth

Because the Southern FIA only estimates growth for the growing-stock portion of the inventory, the gross growth estimates must be adjusted to account for changes in tree class over the period, i.e., trees that changed from growing-stock to cull or vice versa because of tree deterioration, growth, or cruiser judgement. The changes in tree class cause imbalances in the growth estimates due to growing-stock trees being included in one survey but not the other. The adjustment is handled through the cull increment component, which can either increment or decrement the gross growth estimate, depending on the net result of summing the sound-to-cull and cull-to-sound subcomponents. The sound-to-cull subcomponent accounts for trees that changed from growing stock to cull over the period and decreases the gross growth estimate. The cull-to-sound subcomponent accounts for trees that changed from cull to growing stock and increases the gross growth estimate.

In the north unit, cull increment has a positive net effect (more volume went from cull-to-sound than sound-to-cull), increasing the gross growth estimate by half of 1 percent. The sound-to-cull subcomponent is comprised of smaller trees than the cull-to-sound subcomponent. This indicates a tendency for cruisers to give smaller trees the benefit of the doubt when initially assigning a tree class, with the reclassification to cull occurring in subsequent surveys when the impacts of normal development and disturbances can be better assessed. In contrast, the cull-to-sound reclassification occurs more frequently in larger hardwood trees. This is primarily the result of cruiser subjectivity due to the higher incidence of decay and deformity within larger hardwoods.

Net Growth

Net growth is a measure of the increment of the initial inventory subsequent to the impacts of natural tree mortality. The mortality component accounts for the drain on the initial inventory caused by natural tree mortality. In the north unit, the vast majority, 86 percent, of the mortality component estimate is due to the death of larger trees accounted for in the mortality subcomponent. However, the mortality ingrowth subcomponent is also responsible for a sizeable proportion as a result of high levels of mortality in the smaller size classes due to tree competition as part of normal stand development. As might be expected then, this subcomponent's volume was concentrated in the generally more intolerant softwoods. The same estimate of mortality ingrowth is used in both the mortality growth and mortality components. As a result, mortality ingrowth has no net effect upon the net growth or net change estimates. But, because it does provide a better estimate of the mortality occurring over the period, it is included and will impact the gross growth estimate.

Decrementing the adjusted gross growth estimate for the impact of natural mortality results in a measure of the initial inventory's net growth. In the north unit, the initial inventory experienced an average mortality rate of 1.0 percent per year, resulting in an average net growth of 5.9 percent per year for the period. In total, the initial inventory increased by 57.2 percent over the period.

Net Change

Net change is a measure of the difference between the initial and final inventories. It is estimated by reducing the net growth to account for the impacts of man-caused removals over the period. The man-caused removals are accounted for in the cut and landclearing components. Over the period, the north unit experienced an average removals rate of 4.5 percent per year, resulting in an average net change of 1.4 percent per year. On the whole, the initial inventory increased by 13.3 percent over the period. The cut component is responsible for 90 percent of the removals in the unit. Because of the preference for cutting trees in the larger diameter classes, the cut subcomponent accounts for almost all of the cut estimate. This subcomponent is mainly composed of larger trees that were cut and utilized, while the cut ingrowth subcomponent is composed of smaller trees that were mainly killed during logging. Although contributing a small proportion of the total cut estimate, the cut ingrowth subcomponent does provide a better estimate of the cut volume over the period. And like mortality ingrowth, equal estimates of cut ingrowth are included in the cut growth and cut components so that cut ingrowth has no net effect upon the net change estimate. It does, however, impact the gross and net growth estimates. Overall, cutting reduced the initial inventory of the north unit by an average of 4.1 percent per year over the period.

The landclearing component is responsible for the remainder of the total removals estimate. In contrast to the cut component, which is often composed predominantly of softwoods, the landclearing component is generally dominated by hardwoods because of the preference for bottomlands in agricultural conversions. Such was the case in the north unit, where hardwoods comprised over 60 percent of the landclearing component and the softwoods comprised over 60 percent of the cut component.

The ratio of growth to removals for the unit is 1.3, which bodes well for the inventory as a whole. When broken down by species group, the ratios are 1.1 for softwoods and 1.6 for hardwoods. These follow a southwide trend of high utilization of the softwood resource and underutilization of the hardwood resource.

ADDITIVITY

A check for additivity requires consideration of sampling errors. The Southern FIA sampling scheme was designed to provide state-level estimates of forest area and volume with acceptable sampling errors. Sampling error is a function of the inherent variability of the population being sampled and the number of samples taken. In most cases, the larger the sample, the lower the sampling error. Therefore, forest resource statistics for sub-state areas and for finer breakdowns of volume (i.e., growth component volumes) will involve fewer samples and larger sampling errors. The additivity check for the north unit is shown in table 2. The predicted inventory volume (initial inventory plus net change) comes within

2 percent of the actual current inventory. Although not perfectly additive, the predicted inventory is well within the 3.1-percent sampling error of the 1987 inventory. A 95-percent confidence interval about the current inventory spans the range of 4,390.7 to 4,958.7 million cubic feet. This easily encompasses the predicted inventory volume.

Another way of testing the estimate of net change is to compare it with the inventory change (volume #2-volume #1). These two estimates of the intersurvey change (537.8 and 632.8 million cubic feet, respectively) differ by 95.0 million cubic feet. Given the sampling errors for each of these change estimates, (25.6 percent for the net change estimate and 20.7 percent for the inventory change estimate), they are not statistically different (appendix 4). Although mathematical additivity has not been achieved, statistical additivity has.

As expected, the additive approach yielded net change estimates that were almost identical to the inventory change estimates for remeasured plots (appendix 5). The cause of the variability in the net change estimate can best be described as the difference between the reconciled initial inventory, used to calculate net change, and the actual initial inventory, used to calculate inventory change. The difference is usually due to differences in volume estimation techniques or in field procedures. The first of these differences (volume estimation techniques) is ameliorated by matching trees in the initial inventory with trees in the current inventory. This ensures that the initial volume and the reconciled initial volume are the same for each remeasured tree. Since the initial and current volumes are calculated by using the same deterministic volume equation, any growth component changes are truly representative of biological change for each tree.

The second of these differences (field procedures) is an inherent part of the survey and will always be present. These field differences include trees missed in either survey, substituted plots or points because the original could not be found, substituted points because of proximity to nonforest conditions, inaccessible plots (which receive the average plot volume for the county), and forked trees that (because of growth) are now considered to have only one stem. The differences resulting from these add to the variability of the growth estimates, but fortunately they occur infrequently. They are also responsible for the minor difference between the plot volume totals for the actual initial inventory (661,000 cubic feet) and reconciled initial inventory (660,500 cubic feet).

Table 2.—*Additivity check for Mississippi's north unit, 1977-87*

Additivity	Softwood	Hardwood	Total
	Million cubic feet		
Initial inventory, 1977	1,791.4	2,250.5	4,041.9
Net change	+124.0	+413.8	+537.8
Predicted current inventory, 1987	1,915.4	2,664.3	4,579.7
Actual current inventory, 1987	1,955.7	2,718.9	4,674.7
Difference	-40.3	-54.6	-95.0

Therefore, forest population differences due to additions to or deletions from the forest land base as a result of reversions or landclearings are responsible for most of the nonadditivity occurring in the north unit. As previously stated, the true number of reverted acres is unknown under the current sampling scheme. Thus, reverted plots receive the average growth for remeasured plots. Over a large enough sample (state-level), this method of allocating growth to reverted acres should work reasonably well because some reversions have inventory volumes and some do not. This approach, however, can cause additivity problems if there are not enough reverted plots without inventory volume to counterbalance those with inventory volume. In order for mathematical additivity to occur, the net change assigned to the reverted acres should match the inventory on the reverted acres. In most instances, this would certainly overestimate growth on the reverted acres over the period.

One other quirk with this method of handling reversion growth is that for counties where removals exceed growth, the net change volume assigned to the reverted acreage will be negative. Although cutting does occur on reversions, it seems reasonable that it would not be high enough to cause reversions to have negative net change estimates. Fortunately, this problem is relatively small.

The impact of the current method of handling reversion growth in the north unit can be approximated by determining the difference between the current inventory on the 66 reversions in the unit and the estimated net change assigned to the reversions. The current inventory for the 66 reversions was 197.7 million cubic feet, and the net change volume assigned to these reversions totaled 72.0 million cubic feet. This is 125.7 million cubic feet shy of mathematical additivity. This net change estimate translates to an annual change rate of 3.7 percent for the period, suggesting that the average growth assigned to the reversions was out of proportion to the actual inventory on the reversions. This is due in part to the 11 reversions that had no inventory volume but still had an average net change assigned. Therefore, predicting a reasonable estimate of reversion growth may be preferable to achieving additivity, which would result in even higher rates of change on reversions.

Additivity problems also show up with the current method of handling landcleared plots. In landclearings, the initial inventory of the plot is removed from the inventory. Since the actual number of landcleared acres is unknown, the expected number of acres a plot should represent (5,760) is used to expand the plot volumes to the county. Using 5,760 acres is a fair enough assumption given a large enough sample. However, additivity problems occur because the expected expansion factor seldom matches the initial inventory expansion factor. In the north unit, the estimated initial inventory of the

35 cleared plots was 177.3 million cubic feet, while the actual initial inventory was 191.0 million cubic feet. In terms of additivity, landclearing volume was underestimated.

When both landclearing and reversion additivity problems are taken into account, the net change for the unit is underestimated by 112.1 million cubic feet. When the net change estimate is adjusted for this difference, the estimated inventory comes within 0.4 percent of the actual inventory. However, because the number of acres reverted or landcleared over the period is unknown, the effects upon additivity can only be estimated and should only serve to reveal two major sources of nonadditivity in the Southern FIA net change estimates.

In conclusion, all forest survey statistics are sample estimates and each has an associated sampling error. For estimates of forest growth, the variability of the estimates can be quite large. With this in mind, as well as an understanding of some of the major sources of variability and nonadditivity in the growth estimates, the growth components provide reasonable and unbiased estimates of the unit's growth, removals, and mortality while providing a statistically additive estimate of net change.

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Appendix 1.—Definitions

Current—refers to the second survey or time of death for mortality and cut trees.

Past—refers to the first survey.

Ground use - 20 = forest
> 20=nonforest due to land use change

Sample kind - 4 or 6=remeasured plots

Tree class and past tree class—10 and 20=growing stock trees
30=rough cull
40=rotten cull

D.b.h. - must be at least 5.0 inches to be included in growing stock growth. Softwoods must be at least 9.0 inches to be included in sawtimber growth, and hardwoods must be at least 11.0 inches to be included in sawtimber growth.

Tree size—3=sawtimber
2=pole
1=sapling

Tree histories—1, 11, 12, 15=survivor trees
3=ongrowth tree
21, 22=mortality trees
31, 32, 33, 34=cut trees
35, 36, 37, 38=landclearing trees (21, 22 also included if on a landcleared plot)

Distance—7.1 feet=limiting distance for minimum size (5.0-inch) growing stock growth tree.
12.8 feet=limiting distance for minimum size (9.0-inch) softwood sawtimber growth tree.
15.6 feet=limiting distance for minimum size (11.0-inch) hardwood sawtimber growth tree.

Elapsed time—refers to the intersurvey period (in years).

Rem. exp. factor—refers to the remeasured expansion factor=acres represented by one remeasured plot in a county at the time of the second survey or 5,760 acres/plot for landclearing plots.

Appendix 2.—Mississippi Growth Components and Tree Filters for Growing Stock, 1987

Growing Stock (in cubic feet)

Gross growth = survivor growth + ingrowth + mortality growth + cut growth

Adjusted gross growth = gross growth – sound to cull + cull to sound

Net growth = adjusted gross growth – mortality

Net change = net growth – cut – landclearing

Survivor growth = (a + b)

(a) Sum of [(current volume * current trees/acre – past volume * past tree/acre) * rem. exp. factor/elapsed time]

Filters: ground use = 20
sample kind = 4 or 6
tree class = 20
past tree class = 10 or 20
d.b.h. and past d.b.h. > = 5.0 inches
tree histories = 1, 11, 12, 15

(b) Nongrowth = sum of (current volume * current trees/acre * rem. exp. factor/elapsed time)

Additional filters: tree history = 3
distance > 7.1 feet
past d.b.h. > = 5.0 inches

Ingrowth

Sum of (current volume * current trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
tree class =20
d.b.h. > = 5.0 inches
past d.b.h. < 5.0 inches
tree histories = 1, 11, 12, 15

Additional filters for ongrowth trees:
tree history = 3
distance < = 7.1 feet or past d.b.h. < 5.0

Mortality growth = (a + b)

(a) Sum of [(current volume – past volume) * past trees/acre * rem. exp. factor/elapsed time]

Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
d.b.h. and past d.b.h. > = 5.0 inches
tree histories = 21 or 22

(b) Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
d.b.h. > = 5.0 inches
past d.b.h. < 5.0 inches
tree histories = 21 or 22

Cut growth = (a + b)

(a) Sum of [(current volume – past volume) * past tree/acre * rem. exp. factor/elapsed time]

Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
d.b.h. and past d.b.h. > = 5.0 inches
tree histories = 31, 32, 33, 34

(b) Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
d.b.h. > = 5.0 inches
past d.b.h. < 5.0 inches
tree histories = 31, 32, 33, 34

Mortality

Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
d.b.h. and past d.b.h. > = 5.0 inches
tree histories = 21 or 22

Additional filters for mortality ingrowth trees:
d.b.h. > = 5.0 inches
past d.b.h. < 5.0 inches

Cut

Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
d.b.h. and past d.b.h. > = 5.0 inches
tree histories = 31, 32, 33, 34

Additional filters for cut ingrowth trees:
d.b.h. > = 5.0 inches
past d.b.h. < 5.0 inches

Landclearing

Sum of (past volume * past trees/acre * rem. exp. factor/elapsed time)

Filters: ground use > 20
past tree class = 10 or 20
past d.b.h. > = 5.0 inches
tree histories = 21, 22, 35, 36, 37, 38

Cull increment

Sound to cull = sum of (past volume * past trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
tree class > 20
past tree class = 10 or 20
past d.b.h. > = 5.0 inches
tree history = 11

Cull to sound = sum of (current volume * current trees/acre * rem. exp. factor/elapsed time)

Filters: ground use = 20
sample kind = 4 or 6
tree class = 20
past tree class > 20
past d.b.h. > = 5.0 inches
tree history = 11

Appendix 3—Mississippi Growth Components and Tree Filters for Sawtimber, 1987

Sawtimber (in board feet International ¼ rule)
Gross growth = survivor growth + ingrowth + mortality growth + cut growth
Adjusted gross growth = gross growth − sound to cull + cull to sound
Net growth = adjusted gross growth − mortality
Net change = net growth − cut − landclearing
Survivor growth = (a + b)
(a) Sum of [(current volume * current trees/acre − past volume * past trees/acre) * rem. exp. factor/elapsed time]
Filters: ground use = 20
sample kind = 4 or 6
tree class = 20
tree size and past tree size = 3
tree histories = 1, 11, 12, 15
(b) Nongrowth = sum of (current volume * current trees/acre * rem. exp. factor/elapsed time)
Additional filters: tree history = 3
softwood-distance > 12.8 feet and past d.b.h. >= 9.0 inches
hardwood distance > 15.6 feet and past d.b.h. >= 11.0 inches
Ingrowth
Sum of (current volume * current trees/acre * rem. exp. factor/elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
tree class = 20
tree size = 3
past tree size < 3
tree histories = 1, 11, 12, 15
Additional filters for ongrowth trees:
tree history = 3
softwood-distance <= 12.8 feet or past d.b.h. < 9.0 inches
hardwood-distance <= 15.6 feet or past d.b.h. < 11.0 inches
Mortality growth = (a + b)
(a) Sum of [(current volume − past volume) * past trees/acre * rem. exp. factor/elapsed time]
Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
tree size and past tree size = 3
tree histories = 21 or 22
(b) Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
tree size = 3
past tree size < 3
tree histories = 21 or 22

Cut growth = (a + b)
(a) Sum of [(current volume − past volume) * past trees/acre * rem. exp. factor/elapsed time]
Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
tree size and past tree size = 3
tree histories = 31, 32, 33, 34
(b) Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
tree size = 3
past tree size < 3
tree histories = 31, 32, 33, 34
Mortality
Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
tree size and past tree size = 3
tree histories = 21 or 22
Additional filters for mortality ingrowth trees:
tree size = 3
past tree size < 3
Cut
Sum of (current volume * past trees/acre * rem. exp. factor/elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
past tree class = 10 or 20
tree size and past tree size = 3
tree histories = 31, 32, 33, 34
Additional filters for cut ingrowth trees:
tree size = 3
past tree size < 3
Landclearing
Sum of (past volume * past trees/acre * rem. exp. factor/elapsed time)
Filters: ground use > 20
past tree class = 10 or 20
past tree size = 3
tree histories = 21, 22, 35, 36, 37, 38
Cull increment
Sound to cull = sum of (past volume * past trees/acre * rem. exp. factor/elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
tree class > 20
past tree class = 10 or 20

past tree size = 3
tree history = 11
Cull to sound = sum of (current volume * current trees/acre * rem. exp. factor/ elapsed time)
Filters: ground use = 20
sample kind = 4 or 6
tree class = 20
past tree class > 20
past tree size = 3
tree history = 11

Appendix 4.—*Test for equality between the means of net change and inventory change estimates expanded to county level* [1]

VARIABLE: VOL.

Method[2]	N	MEAN	STD DEV	STD ERROR	MINIMUM	MAXIMUM	VARIANCES	T	DF	PROB >|T|
1	689	780599.468795	5237961.32335	199550.433858	-24627064.0000	18592476.0000	UNEQUAL	-0.2050	1395.1	0.8376
2	758	834764.084433	4765964.78976	173107.636446	-20747108.0000	14844834.0000	EQUAL	-0.2060	1445.0	0.8369

[1]FOR HO: VARIANCES ARE EQUAL, F' = 1.21 WITH 688 AND 757 DF. PROB > F' = 0.0112. SAS t-test procedure.
[2]Method 1—plot level net change estimates.
Method 2—plot level inventory change estimates.

Appendix 5.—*Test for equality between the means of net change and inventory change estimates for remeasured plots*[1]

VARIABLE: VOL.

Method[2]	N	MEAN	STD DEV	STD ERROR	MINIMUM	MAXIMUM	VARIANCES	T	DF	PROB >|T|
1	654	164.46685321	733.98258550	28.70099029	-3140.15300000	2026.20400000	UNEQUAL	-0.0714	1305.8	0.9431
2	654	167.38160245	742.01958390	29.01526180	-2892.80700000	2026.18700000	EQUAL	-0.0714	1306.0	0.9431

[1]FOR HO: VARIANCES ARE EQUAL, F' = 1.02 WITH 653 AND 653 DF. PROB > F' = 7809. SAS t-test procedure.
[2]Method 1—plot level net change estimates.
Method 2—plot level inventory change estimates.

May, Dennis M. Forest growth of Mississippi's north unit—a case study of the Southern Forest Survey's growth estimation procedures. Resour. Bull. SO-134. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1988. 9 p.

Data collected from a 1977-87 survey in north Mississippi are used to demonstrate how trees on horizontal point samples are classified into one of eight growth components and, in turn, how these components are combined to derive estimates of forest growth.

Additional keywords: gross growth, net growth, net change, additivity.

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